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MODELING CASUALTY SUSTAINMENT DURING PEACEKEEPING OPERATIONS

G. J. Walker

C. G. Bloodl

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NAVAL HEALTH RESEARCH CENTER
P. O. BOX 85122
SAN DIEGO, CA 92186-5122

BUREAU OF MEDICINE AND SURGERY (M2)
2300 E ST. NW
WASHINGTON, DC 20372-5300

Modeling Casualty Sustainment During Peacekeeping Operations

G. Jay Walker*

Christopher G. Blood

Naval Health Research Center
P.O. Box 85122
San Diego, California 92186-5122

*GEO-CENTERS, Inc.
7 Wells Avenue
Newton, MA 02459

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SUMMARY

Problem

With the greater prospect for U.S. forces to be engaged in nonconventional warfare, casualty forecasts are needed for peacekeeping operations to accurately assess the medical resources and personnel needed to support these operations.

Objective

The present report details a casualty rate projection model for peacekeeping operations at the field hospital level of care. The methodology for projecting incidence rates of killed-in-action (KIA), wounded-in-action (WIA), and disease and non-battle injury (DNBI) rates is presented.

Approach

Data were extracted from electronic sources detailing the duration, force size, and number of fatalities for United Nations peacekeeping missions. KIA rates were then computed for missions in which U.S. forces had participated or that were conducted in regions where the United States has had a presence or interest in the past. Additional accounts of separate peacekeeping incidents in which casualties were sustained were extracted and used to estimate WIA casualty rates. Other published sources were reviewed to derive rates of DNBI incidence during peacekeeping missions. The derived rates were tested to determine the best distributional fit for the data, and subsequently a lognormal probability density function was applied to obtain casualty estimates corresponding to various percentile values of the rate distribution.

Results and Conclusions

A peacekeeping casualty model was developed that uses threat level, force size, and expected operational duration to forecast anticipated casualties. The model projects mean KIA, WIA, and DNBI incidence, and the expected casualties at various percentile levels.

Modeling Casualty Sustainment During Peacekeeping Operations

Modeling casualty rates for peacekeeping missions to ensure the deployment of appropriate levels of medical resources necessitates departures from the traditional methods used to forecast casualties during conventional warfare. While conventional warfare models often assume a daily combat casualty stream with battle injuries incurred on a regular basis, peacekeeping casualty occurrence is often sporadic, with periods of little or no battle wounds punctuated by occasional periods of casualties for a day or several days in a row.[1] Moreover, casualty rates in peacekeeping usually will be only a small fraction of that observed in conventional operations. For example, a British peacekeeping force in Bosnia went more than 6 months without recording a single combat casualty.[2] Other operations have had wounded-in-action (WIA) rates as low as 1 or 2 casualties per 1000 troops per year for periods exceeding 12 months or longer.[3,4] Yet because peacekeeping missions are typically sent to areas of turmoil or regions with unstable political or civil environments, the potential for accelerated combat casualty incidence exists. This potential for substantial casualty sustainment over relatively brief periods of time is underscored by the experiences of peacekeeping forces deployed to Lebanon in 1983 and to Somalia in 1993.[5,6]

While battle wound incidence across peacekeeping operations is marked by considerable variability, medical admissions in the form of disease and non-battle injuries (DNBI) are typically observed in a substantially more uniform patient stream. Though fluctuations in DNBI incidence are generally not as dramatic as the sporadic pulses in combat casualty incidence, the steady flow of DNBI patients during peacekeeping operations represents a facet of operations that likewise must be planned for to ensure adequate medical resources.

This paper outlines a model for projecting medical admissions during peacekeeping operations, discussing first the techniques for forecasting combat-related injuries, and then for estimating DNBI admissions. A method for forecasting the average number of casualties will be described, followed by a section for detailing a method to estimate casualty occurrence at various probability levels. Typically, the techniques used in the past to model casualties for conventional operations have included a review of the rates at which casualties were sustained in similar operations in the past, an examination of the troop population at risk in the imminent operation, and an assessment of the statistical distributions underlying casualty incidence.[7] While the present investigation will employ similar methods in developing the projections for casualties during

peacekeeping operations, this modeling effort will also include modifications that address some of the differences between peacekeeping missions and conventional operations.

Casualty Incidence – Baseline Rates

Since much of the available casualty information on peacekeeping operations comes from missions conducted under a United Nations (UN) mandate, data from UN operations were used to provide the baseline killed-in-action (KIA) rates for the peacekeeping casualty model. The UN maintains records of the fatalities recorded in its peacekeeping missions over the past 50 years.[8] Through January 2003, a total of 1803 fatalities had been recorded, and hostile actions accounted for 32.3% of these fatalities. It is noted that while data on the numbers of casualties incurred in the UN peacekeeping missions are often obtainable, populations-at-risk often fluctuate, and obtaining reliable data on these force sizes is often challenging.

Because the current effort seeks to develop a modeling capability that can realistically simulate the expected levels of casualties among United States troops participating in peacekeeping operations, only prior UN operations in which U.S. troops were involved or which occurred in regions where the U.S. has had an interest in the past were used to derive baseline rates. Consequently, 10 UN operations were chosen to determine the rates of casualties sustained. Those operations were the UN Protection Force in the former Yugoslavia (UNPROFOR), UN Preventive Deployment Force in Macedonia (UNPREDEP), UN Confidence Restoration Operation in Croatia (UNCRO), UN Support Mission in Haiti (UNSMIH), UN Operation in Somalia II (UNOSOM II), UN Disengagement Observer Force in the Syrian Golan Heights (UNDOF), UN Iraq-Kuwait Observer Mission (UNIKOM), UN Interim Force in Lebanon (UNIFIL), and UN Emergency Forces in the Suez Canal sector and the Sinai Peninsula I and II (UNEF I, UNEF II). The KIA rates for these operations ranged from 0.00 to 2.81 per 1000 strength per year with a mean of 0.71 and a median of 0.46.[9-11]

In an effort to accommodate the variation observed among the casualty rates in past operations, the concept of “threat level” was incorporated into the peacekeeping casualty model. While conceptually related to designations of “battle intensity” that are used in conventional combat models, even the highest threat level in the peacekeeping model would be regarded as having a casualty rate substantially below that of low intensity in conventional warfare.

The baseline KIA rates for four different threat levels were determined by stratifying the casualty rates observed during the ten UN operations as follows:

Threat Level 1 – average of the three UN operations with the 1st to 3rd lowest rates
Threat Level 2 – average of the four UN operations with the 3rd to 6th lowest rates
Threat Level 3 – average of the four UN operations with the 3rd to 6th highest rates
Threat Level 4 – average of the three UN operations with the 1st to 3rd highest rates

This resulted in the following estimated baseline KIA rates (per 1000 troops per year):

KIA Baseline Rates (Annual Rates per 1000 Troops)

Threat Level 1 – 0.04
Threat Level 2 – 0.32
Threat Level 3 – 0.59
Threat Level 4 – 1.70

Estimating the WIA rates using the UN data was not possible since the UN only recorded information on fatalities and not the numbers injured. Rather, to derive WIA rates, an estimate of the ratio of WIA to KIA casualties was made for peacekeeping operations using two sources. First, news accounts of casualty incidents during peacekeeping operations were examined for a 15-year period from 1986 to 2000. Utilizing the WestNews® service, electronic searches were performed using the key terms "peacekeeping" (and all variations), "casualties," "injured," "wounded," "deaths," and "killed". This identified 188 incidents of sustained casualties due to hostile action. In these incidents, a total of 162 personnel were killed and 722 were wounded, giving a ratio of 4.46 troops wounded for every KIA victim.

As a second source, the number of KIA and WIA casualties were examined for the 4-month period following the cessation of major combat operations in Operation Iraqi Freedom on May 1, 2003. During this period, U.S. forces sustained 67 killed and 574 wounded, a ratio of 8.57 wounded for every soldier killed.[12] The average of these two ratios (4.46 from the WestNews service data and 8.57 from the Operation Iraqi Freedom aftermath) is 6.51. Thus, a value of 6.51 was applied to the estimated KIA rates at each threat level to yielded the following estimated baseline WIA rates for the various threat levels:

WIA Baseline Rates (Annual Rates per 1000 Troops)

Threat Level 1 – 0.26
Threat Level 2 – 2.08
Threat Level 3 – 3.84
Threat Level 4 – 11.07

These values were then used in the formulas for estimating the mean number of KIA and WIA casualties based on a (force size) x (duration) x (rate) type of model:

Expected KIA Casualties =
(Force Size/1000) x (Duration in Days/365) x (KIA Threat Level Rate)

Expected WIA Casualties =
(Force Size/1000) x (Duration in Days/365) x (WIA Threat Level Rate)

In those instances where deployed troops may be at varying degrees of risk within the same general deployment area, the model is designed so that the user can enter different numbers of troops for each threat level. An overall mean casualty rate is then computed by weighting the rate at each threat level by the number of troops at that level.

Casualty Incidence – Percentile Estimates

Besides information on the average number of expected casualties, military medical planners should be provided with an awareness of the range of possible casualties. While peacekeeping missions are typically fairly benign, the possibility exists that events such as ambushes, targeted attacks, and combat skirmishes may transpire. If medical needs are to be met, planners must anticipate the chance for such high-casualty incidents and assess their impact on needed medical assets. The problem of unanticipated casualties can become exacerbated when resulting shortfalls are in resources that are costly or difficult to obtain, such as certain medical specialists or types of medical equipment. Conversely, if operations are taking place in a theater where capable medical facilities reside nearby and where resupply is readily available, the planner may feel secure in providing in-theater medical resources at a level less than what might be required in a worst-case scenario, knowing the shortfall can be readily rectified.

The peacekeeping model allows the planner to view the range of casualty rates that might be sustained, as well as the likelihood associated with each rate. This is accomplished by a

presentation of the rates that correspond to various percentiles levels. Thus, the planner is able to view the magnitude of elevated casualty rates that would be expected to be sustained in only 20% or less of similar operations (80th percentile) or even rates expected 5% or less of the time (95th percentile). This function will allow the operation to be supplied at the casualty level that the planner feels is necessary to ensure that adequate resources will be available. The trade-off is that there is a greater chance of oversupply when the higher percentile values are used, so cost factors will have to be weighed against expected medical need.

To develop the percentile estimates for rates once a mean value was derived, the casualty incidence data for the 10 previously-discussed UN operations were tested against various statistical distributions to determine the most representative fit to the data (using BestFit® Software).[13] While the number of data points used to fit the distributions was small, three distributions showed markedly better results than the others – the weibull, lognormal, and gamma. Further, none of the three distributions was a significantly better fit than the other two. Because of its relative ease in simulating mathematically, the lognormal distribution was selected for use in determining the rate estimates corresponding to various percentile values.

To calculate the percentile values, 1000 variates are first generated by the model after the user defines the parameters of the operation. These variates are based on a lognormal distribution utilizing the casualty rate value (equal to the baseline rate for the user-defined threat level) as the mean, and a standard deviation equal to 1.17 times the mean. This value of 1.17 represents the overall ratio (standard deviation to the mean) found in the KIA rates for the ten UN operations. Percentile values for WIA casualties are calculated in a similar manner, substituting the baseline WIA rates for the KIA rates.

Example – A peacekeeping operation is expected to last for 10 months (300 days) with 3000 troops at Threat Level 3. For Threat Level 3, the baseline KIA rate is 0.59. Therefore,1000 lognormal variates are generated using a mean of 0.59 and a standard deviation of (1.17 x 0.59) or 0.69. Using these values for the mean and standard deviation along with a random number generator, the first random lognormal variate generated in this example had a value of 0.489. The associated number of expected KIA casualties for this first iteration is then .489 x (3000 troops/1000) x (300 days/365) or 1.21. This process is repeated for 1000 iterations, yielding 1000 values for expected KIA casualties. Percentile values are then calculated from these 1000 estimated values. In the simulation run for this particular example, the 95th percentile value

showed an expectation of four hostile deaths, while the 50th percentile value estimated one hostile death.

<u>Casualty Incidence – Small Force Size Adjustment</u>

At times, a peacekeeping operation may employ relatively few troops in what is felt to be a fairly benign environment like peace monitoring or humanitarian relief, only to see the situation become unstable. In such operations, the actual number of casualties can well be greater than might normally be predicted with the aforementioned algorithms, due to the fact that the multiplicative features of the model tend to produce low casualty estimates for small forces.

Consequently, an adjustment was made to the percentile estimates for cases where the force size is quite small, specifically under 1000 troops. For this adjustment, the standard deviation value used in the model (i.e., 1.17 times the baseline mean rate) is increased by a multiplier. This multiplier is set to 1.0 for forces of 1000 troops (or more) and gradually increased as an inverse linear function to a maximum value of 1.50 for a force size of 500 troops (or less). By way of example, when estimating casualties for a force of 500 troops at Threat Level 3, lognormal variates will still be generated using a mean value equal to the baseline KIA rate of 0.59, but now with a modified standard deviation of (0.59 x 1.17 x 1.50) or 1.04.

<u>Disease and Non-Battle Injury Incidence – Baseline Rates</u>

The nature and rate of occurrence of DNBI casualties during peacekeeping missions differs from that of combat casualties. The frequency of DNBI casualties typically resembles a steady stream rather than a series of infrequent and sporadic incidents as is seen with battle-related wounds during peacekeeping. Because of this difference in incidence, the rates for peacekeeping DNBI casualties will be expressed as a daily rate per 1000 strength instead of as an annual rate as was used in projecting KIA and WIA casualties.

The recording of DNBI admissions and populations-at-risk during peacekeeping missions often has been a low priority. Among previous peacekeeping operations that seemed to go to some lengths to accurately record DNBI hospitalizations was Operation Resolute, a British operation to Bosnia in 1996. An associated report states "… a designated reporting officer was identified at each of the hospital facilities. The hospital returns were collected each month and

sent to HQ… (the reporting officer) was briefed at each location to ensure maximum participation from the units…”.[2] The data collected from this deployment indicated that from July to November 1996, Operation Resolute recorded 0.41 DNBI hospitalizations per 1000 troops per day.[2]

A parallel U.S. operation in Bosnia was called Operation Joint Endeavor, and the inpatient hospitalization rate for that operation was reported as 0.12 per 1000 troops per day.[14] However, this operation covered a 16-month period and showed sharply declining rates as the operation wound down and as another operation, Operation Joint Guard, was preparing to replace it. The hospitalization rate for a 30-week period (from December 1995 to July 1996) that would be regarded as the active part of the operation showed a hospitalization rate of 0.25 per 1000 per day.[15] There is, however, some indication that the hospitalization data capture was not complete for this operation.[16]

Another report recorded the DNBI hospitalizations for the UN operation in Haiti (UNMIH) for a 19-week period in 1995.[17] While the UN force size during the reporting period is not known with complete accuracy, the UN Web site states that the peak force for the UNMIH operation was 6000 troops.[18] The maximum possible hospitalization rate for this operation thus would be 0.47 per 1000 per day.

The operations cited above set some probable ranges for hospitalization rates during peacekeeping operations. With these limited data, the following rates were considered appropriate for baseline estimates at the various threat levels. These rates are expressed in troops per 1000 per day with the associated annual rate in parentheses:

DNBI Baseline Rates, European Theaters - Daily (and Annual) Rates per 1000 Troops

Threat Level 1 – 0.33 (120)
Threat Level 2 – 0.37 (135)
Threat Level 3 – 0.41 (150)
Threat Level 4 – 0.46 (168)

These baseline rates are used to project DNBI rates for a peacekeeping operation in a European theater, with considerable weight given to the Operation Joint Endeavor and Operation Resolute missions in Bosnia cited above. However, previous studies of conventional combat have shown that the disease rates for Southwest Asia theaters have been approximately double that of

Europe.[19] These same operations had a non-battle injury (NBI) rate for nondivisional support troops that was 8% higher in Southwest Asia than Europe.[19] Using these figures as a guideline, the DNBI rates for peacekeeping missions in non-European theaters have been set at 30% higher than those in European theaters. Therefore, the baseline DNBI rates for non-Europe missions are as follows (annual rates in parentheses):

DNBI Baseline Rates, Non-European Theaters - Daily (and Annual) Rates per 1000 Troops

Threat Level 1 – 0.43 (156)
Threat Level 2 – 0.48 (175)
Threat Level 3 – 0.53 (195)
Threat Level 4 – 0.60 (218)

Within the overall DNBI rates, separate disease and NBI components are needed to provide greater accuracy in determining the types of medical resources required. Inpatient hospitalization data were examined for troops in Operation Desert Storm and Desert Shield (1990-1991, 12 months), Operation Provide Promise (1992-1994, 17 months), Operation Resolute 2 (1996, 4 months), Operation Joint Endeavor (1995-1996, 12 months) and UN troops in Croatia (1995, 3 months).[2,3,20-22] The percentage of NBI to total DNBI casualties for these operations ranged from 25.0% to 48.3%, with an average of 37.0%. Therefore a 63%-37% split has been used to estimate disease and NBI as percentages of total DNBI casualties.

The formulas used for estimating the expected number of DNBI inpatient casualties parallel those used for battle casualties:

Expected Disease Casualties =
0.63 x (Force Size/1000) x (Duration in Days) x (DNBI Threat Level Rate)

Expected NBI Casualties =
0.37 x (Force Size/1000) x (Duration in Days) x (DNBI Threat Level Rate)

As before, in cases where troops are deployed at different threat levels, an overall mean rate is computed by weighting the rate at each threat level by the number of troops at that level.

Disease and Non-Battle Injury Incidence – Percentile Estimates

Since little information is available on day-to-day DNBI incidence during past peacekeeping missions, historical data from conventional combat were used to aid in deriving the

percentile estimates. Specifically, DNBI incidents and rates were computed for combat and support troops deployed to Vietnam over a 91-day period.[23] The daily DNBI rates were found to be distributed as a lognormal distribution with a standard deviation equal to 0.69 times the mean.

Therefore, to estimate percentile levels for DNBI admissions (as was done for KIA and WIA casualties), 1000 lognormal variates are generated by the developed model, using a mean of the DNBI baseline rate for a particular threat level and region, and a standard deviation of 0.69 times the mean. These variates are then used with the force size and operational duration to compute the 1000 estimates of the number of DNBI casualties. It is from these 1000 numbers that the percentile estimates are computed.

Example – Five thousand troops are deployed on a 120-day peacekeeping mission to Southeast Asia that is judged to be at Threat Level 2. The DNBI baseline rate for a Threat Level 2, non-European mission is 0.48. A simulation of a lognormal distribution is run to generate 1000 variates using a mean of 0.48 and a standard deviation of 0.33 (0.48 x 0.69). The variates are sequentially ordered and then multiplied by the force size and duration to determine the percentile values.

Several examples showing trial runs of the model for different force sizes, durations and threat levels are included in the Appendix. These examples show the daily and annual casualty rates, as well as the expected number of casualties for the various casualty types and the anticipated casualties at various percentile levels.

Summary

The present effort details the methodology and algorithms developed to project KIA, WIA and DNBI admissions during peacekeeping operations. The methodology capitalizes on existing data from previous missions of a similar nature. At this point, it does not incorporate the casualties of adversarial forces and civilians that might present themselves to U.S. medical facilities during such operations. A program was written called PKCAS that utilizes derived algorithms to provide results showing the estimated number of casualties for a projected operation, as well as the expected numbers at various probability levels. This developed model will assist medical planners in determining the ranges of casualty and illness admissions to medical treatment facilities that can be expected during peacekeeping operations.

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Appendix – Sample Runs for Various Peacekeeping Scenarios

Scenario 1 – large force size, longer duration, lower threat levels, non-European theater

Enter Duration in Months ==> 12

	Threat Level 1	Threat Level 2	Threat Level 3	Threat Level 4
Enter the Force Size for each Threat Level (1 to 4) ==>	20000	5000	0	0

Sum of force sizes entered: 25000

Are these troops in a European theater (Y/N) ==> N

	KIA	WIA	DIS	NBI
Estimated number of casualties:	2.4	15.6	2527.0	1484.1
Annual Rate per 1000:	0.1	0.6	101.1	59.4
Daily rate per 1000:	0.0003	0.0017	0.277	0.163
	KIA	**WIA**	**DIS**	**NBI**
95th Percentile	7.2	49.5	6025.4	3416.7
90th Percentile	4.9	33.6	4746.5	2771.3
80th Percentile	3.5	23.0	3549.5	2144.9
70th Percentile	2.6	17.4	2874.8	1756.3
50th Percentile	1.5	11.1	2062.7	1257.3
30th Percentile	1.0	7.0	1449.5	844.0

Scenario 2 – representative force size, mid-term duration, mixed threat levels, Europe

Enter Duration in Months ==> 6

	Threat Level 1	Threat Level 2	Threat Level 3	Threat Level 4
Enter the Force Size for each Threat Level (1 to 4) ==>	2500	2000	1500	1000

Sum of force sizes entered: 7000

Are these troops in a European theater (Y/N) ==> Y

	KIA	WIA	DIS	NBI
Estimated number of casualties:	1.7	10.8	303.6	178.3
Annual Rate per 1000:	0.5	3.1	86.8	50.9
Daily rate per 1000:	0.0013	0.0085	0.238	0.140
	KIA	**WIA**	**DIS**	**NBI**
95th Percentile	4.9	29.6	656.8	418.6
90th Percentile	3.4	22.4	560.7	337.8
80th Percentile	2.3	14.7	421.5	240.8
70th Percentile	1.7	11.6	350.2	201.2
50th Percentile	1.1	7.0	244.8	143.7
30th Percentile	0.7	4.1	177.1	102.8

Scenario 3 – representative force size, short duration, higher threat levels, Europe

Enter Duration in Months ==> 2

	Threat Level 1	Threat Level 2	Threat Level 3	Threat Level 4
Enter the Force Size for each Threat Level (1 to 4) ==>	0	1000	1000	4000

Sum of force sizes entered: 6000

Are these troops in a European theater (Y/N) ==> Y

	KIA	WIA	DIS	NBI
Estimated number of casualties:	1.3	8.4	100.4	59.0
Annual Rate per 1000:	1.3	8.4	100.4	59.0
Daily rate per 1000:	0.0035	0.0229	0.275	0.162
	KIA	**WIA**	**DIS**	**NBI**
95th Percentile	3.5	23.0	229.9	141.2
90th Percentile	2.6	17.1	180.3	111.4
80th Percentile	1.9	11.2	139.7	82.4
70th Percentile	1.4	8.3	114.5	68.4
50th Percentile	0.9	5.2	81.8	48.8
30th Percentile	0.5	3.4	60.5	35.3

Scenario 4 – very small force size, shorter duration, mixed threat levels, non-Europe

Enter Duration in Months ==> 4

	Threat Level 1	Threat Level 2	Threat Level 3	Threat Level 4
Enter the Force Size for each Threat Level (1 to 4) ==>	400	100	0	200

Sum of force sizes entered: 700

Are these troops in a European theater (Y/N) ==> N

	KIA	WIA	DIS	NBI
Estimated number of casualties:	0.1	0.8	26.0	15.3
Annual Rate per 1000:	0.6	3.6	111.5	65.5
Daily rate per 1000:	0.0015	0.0099	0.305	0.179
	KIA	**WIA**	**DIS**	**NBI**
95th Percentile	0.5	2.5	58.1	34.5
90th Percentile	0.3	1.8	46.9	26.6
80th Percentile	0.2	1.1	36.2	20.5
70th Percentile	0.1	0.8	30.2	17.0
50th Percentile	0.1	0.5	22.2	12.4
30th Percentile	0.0	0.3	16.2	9.1

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6. AUTHORS
G. Jay Walker, Christopher G. Blood

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Health Research Center
P.O. Box 85122
San Diego, CA 92186-5122

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13. SUPPLEMENTARY NOTES

14. ABSTRACT (maximum 200 words)

Casualty forecasts for peacekeeping operations allow assessment of the medical resources and personnel needed to support these missions. This report develops a methodology for estimating the casualties that will occur in such operations. Data were extracted from electronic sources detailing the duration, force size and fatalities for United Nations peacekeeping missions, and killed-in-action (KIA) rates were then computed Accounts of peacekeeping incidents in which casualties were sustained were recorded and used to estimate wounded-in-action (WIA) casualty rates. Other data sources were reviewed to derive rates for disease and non-battle injury (DNBI) incidence during peacekeeping missions. The resulting methodology uses the anticipated threat level, force size and estimated operational duration to forecast the expected number of KIA, WIA and DNBI casualties for peacekeeping operations. The distributional properties of casualty occurrence were also investigated to project the number of casualties at various probability levels.

15. SUBJECT TERMS
Casualties, forecasting, peacekeeping, modeling

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